Curriculum of M.Sc. Statistics (CBCS)

New Syllabus

[With effect from 2020-2021]

Department of Statistics
Bharathidasan University
Khajamalai Campus
Tiruchirappalli - 620 023

Department of Statistics

Curriculum Structure

M.Sc. Statistics (CBCS)

New Syllabus

[With effect from 2020-2021]

List of Courses

Total Credits - 95

Internal Marks - 25 and External Marks - 75

Semester	Courses	Total
I	5 Core Courses	24
II	4 Core Courses 2 Department Elective Course 1 Value Added Course	27
III	3 Core Courses 1 Department Elective Course 1 University Elective Course 1 Value Added Course 1 EDC Course	24
IV	1 Core Courses 2 Department Elective Courses 1 Project / Dissertation	20

Department of Statistics

M.Sc. Statistics (CBCS) - New Syllabus - [with effect from 2020-2021]

Semester	Sub. Code	Title of the Course	Credits	Total
I	20ST01CC	Probability Theory	5	24
	20ST02CC	Distribution Theory	5	
	20ST03CC	Sampling Theory	5	
	20ST04CC	R Programming	5	
	20ST05CCL	Statistical Computing Lab – I	4	
II	20ST06CC	Statistical Inference I	5	27
	20ST07CC	Statistical Quality Control and Reliability Theory	5	
	20ST01DEC	Linear Models and Design of Experiments	4	
	20ST02DEC	Stochastic Processes	4	
	20ST08CC	Python Programming	5	
	20ST09CCL	Statistical Computing Lab – II	4	
	20ST01VAC*	VAC-1 - Introduction to Machine Learning	2	
III	20ST10CC	Statistical Inference II	5	24
	20ST11CC	Multivariate Analysis	5	
	20ST03DEC	Econometrics	4	
	20ST01UEC	Operations Research	3	
	20ST12CCL	Statistical Computing Lab – III	4	
	20ST02VAC*	VAC-2 - Introduction to Big Data Analytics	2	
		EDC	3	
IV	20ST04DEC	Survival Analysis and Clinical Trails	4	20
	20ST05DEC	Demography and Official Statistics	4	
	20ST13CCL	Statistical Computing Lab – IV	4	
	20ST14CCPROJ	Project / Dissertation	8	
		Total		95

*** VAC Credits not included in the Total Credits**

List of Core / Department Elective / University Elective / Value Added Courses to be offered

CORE COURSES (CC)

Code	Title of the Course	Lecture Hours	Tutorial Hours	Practical Hours	Credits
20ST01CC	Probability Theory	4	2	0	5
20ST02CC	Distribution Theory	4	2	0	5
20ST03CC	Sampling Theory	4	2	0	5
20ST04CC	R Programming	4	2	0	5
20ST05CCL	Statistical Computing Lab – I	4	0	2	4
20ST06CC	Statistical Inference I	4	2	0	5
20ST07CC	Statistical Quality Control and Reliability Theory	4	2	0	5
20ST08CC	Python Programming	4	2	0	5
20ST09CCL	Statistical Computing Lab – II	4	0	2	4
20ST10CC	Statistical Inference II	4	2	0	5
20ST11CC	Multivariate Analysis	4	2	0	5
20ST12CCL	Statistical Computing Lab – III	4	0	2	4
20ST13CCL	Statistical Computing Lab – IV	4	0	2	4
20ST14CCPROJ	Project / Dissertation	8	4	4	8

DEPARTMENT ELECTIVE COURSES (DEC)

Code	Title of the Course	Lecture Hours	Tutorial Hours	Practical Hours	Credits
20ST01DEC	Linear Models and Design of Experiments	4	2	0	4
20ST02DEC	Stochastic Processes	4	2	0	4
20ST03DEC	Econometrics	4	2	0	4
20ST04DEC	Survival Analysis and Clinical Trails	4	2	0	4
20ST05DEC	Demography and Official Statistics	4	2	0	4
20ST06DEC	Statistical Genetics	4	2	0	4
20ST07DEC	Applied Regression Analysis	4	2	0	4
20ST08DEC	Statistical Methods for Bioinformatics	4	2	0	4
20ST09DEC	Financial Statistics	4	2	0	4
20ST10DEC	Time Series Analysis	4	2	0	4

UNIVERSITY ELECTIVE COURSES (UEC)

Code	Title of the Course	Lecture Hours	Tutorial Hours	Practical Hours	Credits
20ST01UEC	Operations Research	4	2	0	3
20ST02UEC	Bio-Statistics	4	2	0	3
20ST03UEC	Industrial Statistics	4	2	0	3

VALUE ADDED COURSES (VAC)

Code	Title of the Course	Lecture Hours	Tutorial Hours	Practical Hours	Credits
20ST01VAC	Induction to Machine Learning	2	1	0	2
20ST02VAC	Introduction to Big Data Analytics	2	1	0	2
20ST03VAC	Advanced Excel and Data Analysis	2	1	0	2
20ST04VAC	Advanced Data Analysis using SPSS	2	1	0	2

QUESTION PAPER PATTERN FOR UNIVERSITY EXAMINATION
M.Sc. Statistics (CBCS) Degree Examination

Time: 3 Hours Max. Marks: 75

Section - A (10 × 2 = 20 Marks)

Answer all the questions.

Each question carries 2 marks.

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

Section - B (5 × 5 = 25 Marks)

5 Questions (One question from each Unit) with internal choice.

Each question carries 5 marks.

11. (a)

(OR)

(b)

12. (a)

(OR)

(b)

13. (a)

(OR)

(b)

14. (a)

(OR)

(b)

15. (a)

(OR)

(b)

Section - C (3 × 10 = 30 Marks)

Answer any 3 questions.

Each question carries 10 marks.

16.
17.
18.
19.
20.

Award of Degree

- A candidate shall be declared to have passed a certain subject if he/she secures not less than 50% in the total marks (CIA + ESE) and not less than 40% marks in the ESE marks.
- Out of 100 marks for the Project / Dissertation, 25 marks will be for CIA, 75 marks for Evaluation of the Project / Dissertation and the Viva-Voce examination.
- A candidate shall be declared to have passed in the Project / Dissertation work if he/she gets not less than 25% in the aggregate of marks obtained CIA and not less than 50% of the total marks obtained in the three components (CIA, Evaluation and Viva-Voce). However the candidate should compulsorily attend the Viva-Voce examination to pass in the Project / Dissertation.

AIMS

- To provide a theoretical knowledge along with applications based high quality education with a combination of the subjects and Statistical Practical to Post-Graduate Degree level for students who have to demonstrate their ability and potential towards Statistical Theory and Applications.
- To develop knowledge, understanding and experience of the theory and to grow practical expertise in selected areas of statistical computing and to produce graduates needed by industries, public and private sector and to develop analytical and software skills for implementation in Data manipulation in IT companies.
- To develop enterprise competences emphasizing the key skills sets of learning interfacing to some unique job roles.

OBJECTIVES

1. To provide a intrinsic perceptive of the Statistical principles, techniques and applications of selected areas of Statistics and computing
2. The ability to implement and increase the statistical theory in computer software packages which takes into account the needs of the user and constraints towards computational environment.
3. To gain deeper understanding, problem solving skills and greater knowledge of selected topics in statistical computation in Data analytics and Data science

CORE COURSES (CC)

Probability Theory (20ST01CC) (Credits: 5)

Unit – I

Classes of Sets – field – σ-field – Minimal σ-field – Borel field – Sequences of sets – Limit Inferior and Limit Superior of Sequences of Sets – Measure : Definition and Properties – Lebesgue measure and Lebesgue-Stieltjes Measure – Probability Measure – Probability Space – Properties of Probability Measure.

Unit – II

Measurable function – Random Variable – Distribution function – Discrete and Continuous Random Variables – Decomposition of Distribution functions - Expectation and Moments – Properties – Generating functions – Chebyshev's, Markov's, Holder's, Jensen's and Minkowski's Inequalities – Characteristic function – Inversion theorem and Its Applications – Uniqueness theorem.

Unit – III

Modes of Convergence – Convergence in Probability, Convergence in Distribution, Convergence in r^{th} mean almost sure Convergence and their Interrelationships. Weak and Complete Convergences of Distribution functions.

Unit – IV

Independence of Random Variables – Borel-Cantelli Lemma – Kolmogorov's 0-1 Law. Kolmogorov's Inequality – Khintchine's Weak Law of Large Numbers and Kolmogorov's Weak Law of Large Numbers– Kolmogorov's Strong Law of Large Numbers.

Unit – V

Central limit theorems – De Moivre-Laplace, Lindeberg-Levy's, Liapunov's – Lindeberg-Feller's Central limit theorem (statement only). Radon-Nikodym theorem and Derivative (without proof) – Conditional Probability and Conditional Expectation – Properties and Applications. Product Space – Fubini's theorem (statement only) and Its Applications.

Books for Study and References:

1. Bhat, B.R. (1999): Modern Probability Theory (Third Edition). New Age International, New Delhi. (Reprint 2004)
2. Billingsley, P. (2012): Probability and Measure (Third Edition). John Wiley & Sons, New York.
3. Chow, Y.S. and Teicher, H. (2012): Probability Theory: Independence, Interchangeability, Martingales (Second Edition). Springer Limited.
4. Feller, W. (2008): An Introduction to Probability Theory and Its Applications, Volume I (Third Edition), John Wiley & Sons, New York.
5. Rana, I.K. (2005): An Introduction to Measure and Integration (Second Edition). Morgan & Claypool.
6. Rohatgi, V.K. and Saleh, A.K.Md.E. (2011): An Introduction to Probability and Statistics (Second Edition). John Wiley & Sons, New York.

Distribution Theory (20ST02CC) (Credits: 5)

Unit – I

Basic Distribution Theory – Joint, Marginal and Conditional Probability Mass Functions and Probability Density Functions. Standard Distributions: Binomial, Poisson, Multinomial and Normal Probability Distributions. Bivariate Normal Distribution – Properties and Relationships.

Unit – II

Functions of Random Variables and their Distributions – Methods of Finding Distributions: Cumulative Distribution Function - Jacobian of Transformation - Characteristic Function and Moment Generating Function.

Unit – III

Geometric, Negative Binomial, Truncated Binomial, Truncated Poisson, Power Series and Logarithmic Distributions – Properties and Relationships.

Unit – IV

Exponential, Laplace, Logistic, Log-normal, Beta, Gamma, Cauchy and Compound Poisson Distribution. Sampling Distributions – Central-t, Central-F, Central chi-square distributions – Properties and Relationships.

Unit – V

Non-Central t – Non-Central Chi-Square – Non-Central F Distributions and their Properties. Order Statistics: Distribution of r^{th} Order Statistics – Joint Distribution of two or more Order Statistics – Distribution of Sample Range and Median.

Books for Study and References:

1. Catherine Forbes, Merran Evans, Nicholas Hastings, Brian Peacock (2011). Statistical Distributions (Fourth Edition). John Wiley & Sons.
2. Christian Walck (2007): Hand-book on Statistical Distributions for Experimentalists. Particle Physics Group Fysikum. University of Stockholm.
3. Johnson, N.L. and Kotz, S. (1972): Distributions in Statistics, Princeton University Press.
4. Johnson, N.L., Kemp, A.W. and Kotz, S. (2005): Univariate Discrete Distributions (Third Edition). John Wiley & sons, New York.
5. Johnson, N.L, Kotz, S. and Balakrishnan, N. (2004): Continuous Univariate Distributions. Vol. I. John Wiley & sons (Asia), Singapore.
6. Johnson, N.L, Kotz, S. and Balakrishnan, N. (2014): Continuous Univariate Distributions. Vol. II. John Wiley & sons (Asia), Singapore.
7. Karian, Z.A. and Dudewicz, E.J. (2011). Handbook of Fitting Statistical Distributions with R. Chapman & Hall.
8. Rao, C.R. (2009): Linear Statistical Inference and Its Applications (Second Edition). John Wiley & Sons.

Sampling Theory (20ST03CC) (Credits: 5)

Unit – I

Population and Sample – Census and Sample Survey – Sampling – Sampling Unit, Sampling Frame, Sampling Distribution, Standard Error, Questionnaire and Schedule, Sampling Design – Sampling and Non-Sampling Errors – Non Response and its Effects – Sample Surveys – Principles of Sample Survey – Steps in Sample Survey – Limitations of Sampling – NSSO/CSO in India.

Unit – II

Simple Random Sampling (With and Without Replacement): Notations and Terminologies – Estimates of Population Total, Mean and their Variances and Standard Errors – Determination of Sample Size – Pooling of Estimates – Confidence Limits – Simple Random Sampling of Attributes.

Unit – III

Stratified Random Sampling: Estimates of Population Total, Mean and their Variances - Related Properties – Neyman's Proportional and Optimum Allocations – Comparison of Stratified Sampling with Simple Random Sampling – Estimation of Proportion under Stratified Random Sampling.

Systematic Sampling: Estimates of Population Total, Mean, and their Variances and Standard Errors – Systematic Sampling with Linear Trend – Comparison of Systematic Sampling with Stratified and Simple Random Sampling – Circular Systematic Sampling – Two stage Sampling with Equal Number of Second stage Units and Cluster Sampling.

Unit – IV

Varying Probability Sampling: PPS Sampling (With and Without Replacement) – Gain due to PPS Sampling – Stratified PPS – Selection Procedures – Desraj Ordered and Unordered Estimates – Horwitz-Thompson and Murthy's Estimates.

Unit – V

Ratio Estimate – Methods of Estimation, Approximate Variance of the Ratio Estimate - Regression Estimators – Difference Estimators, Regression Estimators in Stratified Sampling - Concepts of Double Sampling.

Books for Study and References:

1. Ardilly, P and Yves T. (2006): Sampling Methods: Exercise and Solutions. Springer.
2. Cochran, W.G. (2007): Sampling Techniques (Third Edition). John Wiley & Sons, New Delhi.
3. Desraj (1976): Sampling Theory. Tata McGraw Hill, New York.(Reprint 1979)
4. Mukhopadyay, P. (2007): Survey Sampling. Narosa Publisher, New Delhi.
5. Stephen K. Thompson (2012). Sampling. (Third Edition). John Wiley & Sons, Canada.
6. Thompson, S.K. (2012). Sampling. John Wiley & Sons.

R Programming (20ST04CC) (Credits: 5)

Unit – I

Introduction to R programming: R-Introduction – Uses of R – Advantages and Disadvantages – Installing R – Installing R Packages – Basic Syntax – Data Types – Import and Export Data.

Unit – II

Data structures and variables: Creating Variables – Operators of R – Decision Making of R – R-Loops – Functions of R.

Unit – III

Descriptive Statistics in R: Mean, Median, Mode, Variance, Standard Deviation and Range.

Statistical Graphs in R: Histogram, Bar Chart, Pie Chart, Box Plot, Scatter Plot.

Sampling – Simple Random Sampling, Stratified Random Sampling.

Unit – IV

Coding of Discrete Distribution – Bernoulli, Binomial, Poisson, Negative Binomial, Geometric and Hyper Geometric Distributions.

Unit – V

Coding of Continuous Distribution - Normal, Lognormal, Exponential, Cauchy, Gamma and Beta Distributions.

Book for Study and References:

1. Gareth James, Daniela Witten, Trevor Hastie and Robert Tibshirani (2017): An Introduction to Statistical Learning: with Applications in R (Springer Texts in Statistics).
2. Maria, L. (2007): Rizzo Statistical Computing with R, Chapman & Hall/CRC.
3. Roger D. Peng (2015): R Programming for Data Science, Lean Publishing.
4. Sandip Rakshit (2017): R Programming for Beginners.
5. Sudha, G. (2008): Statistics Using R, Narosa Publishing House.
6. Tilman M. Davies (2016): The Book of R, No Starch Press, Inc.

Statistical Computing Lab – I (20ST05CCL) (Credits: 4)

The Maximum Mark for this Statistical Computing Lab shall be 100 with 25 Marks for Internal Assessment, which comprises Tests and Record Work with manual procedures, and 75 Marks for External Practical Examination. The candidate should attend 3 questions, and each question has 25 marks both the manual and system results. The contents for this Statistical Computing Lab are the problems related to the topics relating to the areas listed below covered in the current semester. The Core Statistical Computing Lab examination is to be conducted at the end of the current Semester. The contents for Statistical Computing Lab shall be restricted to the following topics, which are found in the software **"R"**.

Probability Theory: Boole's Inequality – Mutual and Pair wise Independent – Baye's Theorem – Chebychev's Inequality – Central Limit Theorem.

Distribution Theory: Joint Probability Distribution Function – Discrete Distribution Function – Continuous Distribution Function – Fitting of Binomial Distribution – Poisson Distribution – Multinomial Distribution – Normal Distribution – Z- Score For Normal Distribution – Negative Binomial Distribution – t- Distribution for Single Mean, Differences Means – F-Distribution – χ^2- Distribution

Sampling Theory: Simple Random Sampling With and Without Replacement – Simple Random Sampling Proportion – Simple Random Sampling Population and Sample Mean – Stratified Random Sampling With Replacement - Systematic Sampling – Ratio Estimation – Cluster Sampling – Estimation of Standard Error Under Ordered and Unordered Estimator.

Book for Study and references:

1. Ardilly, P and Yves T. (2006): Sampling Methods: Exercise and Solutions. Springer.
2. Catherine Forbes, Merran Evans, Nicholas Hastings, Brian Peacock (2011). Statistical Distributions (Fourth Edition). John Wiley & Sons.
3. Karian, Z.A. and Dudewicz, E.J. (2011). Handbook of Fitting Statistical Distributions with R. Chapman & Hall.
4. Stephen K. Thompson (2012). Sampling. (Third Edition). John Wiley & Sons, Canada.
5. Rohatgi, V.K. and Saleh, A.K.Md.E. (2011): An Introduction to Probability and Statistics (Second Edition). John Wiley & Sons, New York.
6. Feller, W. (2008): An Introduction to Probability Theory and Its Applications, Volume I (Third Edition), John Wiley & Sons, New York.

Statistical Inference - I (20ST06CC) (Credits: 5)

Unit – I

Estimator – Estimate – Characteristics of a good Estimator: Consistency – Sufficient condition for Consistency – Unbiasedness – Sufficiency – Factorization Theorem – Minimal Sufficiency, Efficiency – Most Efficient Estimator, Likelihood Equivalence – Uniformly Minimum Variance Unbiased Estimator – Rao-Blackwell and Lehmann-Scheffe's theorems.

Unit – II

Mean-Squared Error - Fisher's Information Measure – Cramer-Rao Inequality – Applications, Minimum Variance Bound(MVB) Estimators, Bhattacharya Inequality, Chapman – Robbins Inequality – Exponential family of Distribution of Single Parameter and k Parameter, Complete Sufficient Statistic – Asymptotic Relative Efficiency

Unit – III

Methods of Point Estimation – Maximum Likelihood Method (the Asymptotic Properties of ML Estimators are not included), Method of Moments, Method of Least Square, Method of Minimum Chi-Square and Modified Minimum Chi-Square-Asymptotic Maximum Likelihood Estimation.

Unit – IV

Interval Estimation – Pivotal Quantity Method. Shortest length Confidence Intervals. Construction of Confidence Intervals for Population Proportion (Small and large Samples) and between two Population Proportions (large Samples) – Confidence Intervals for mean, Variance of a Normal Population – difference between Mean and Ratio of two Normal Populations.

Unit – V

Bayes' Estimation – Bayes' Risk – Informative – Non Informative – Natural Conjugate-Principle of Equivariance – Minimum Risk Equivariant Estimator – Pitman Estimator Credible Intervals – Bayes' factor for testing Hypothesis – Frequentist test for one-sided Hypothesis and two-sided Hypothesis.

Books for Study and References:

1. Bagdonavicious, Kruopis, M.S. Nikulin (2011): Non-Parametric Tests for Complete Data, First Edition, John Wiley and Sons, USA.
2. Kale, B.K. (1999): A First Course on Parametric Inference, Narosa Publishing House, New York.
3. Lehman, E.L., and G. Cassella (1998): Theory of Point Estimation (II Edition), Springer, NY.
4. Rohatgi, V.K. (1992): An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Ltd., New Delhi.
5. Radhakrishna Rao. C (2009): Linear Statistical Inference and Its Applications, Wiley.
6. William M. Bolstad (2007): Introduction to Bayesian Statistics, 2nd edition, John Wiley, NY

Statistical Quality Control and Reliability Theory (20ST07CC) (Credits: 5)

Unit – I

Quality – Basis of SQC – Benefits – Process and Product Control – Parts of Control Charts – Shewhart Control Charts for $\bar{X}$, R, s, p, np, c, u etc., and Their Uses. OC and ARL of Control Charts, Control Charts based on C.V.

Unit – II

Process Capability Analysis – Gauge Capability Analysis – CUSUM procedures, Use of V-mask, – Decision Interval Schemes for CUSUM Charts. Economic Designs of Control Charts – Relative Precision – Multivariate Control Charts.

Unit – III

Basic Concepts of Acceptance Sampling – Sampling Inspection – 100% Sampling Inspection – Sampling Inspection by Attributes – Single, Double, Multiple and Sequential Sampling Plans – OC, ASN, ATI and AOQ functions, Curtailed Sampling – MIL-STD-105E – LTPD and AOQL Protection (Single Sampling Plan only).

Unit – IV

Variable Sampling Plan: Assumptions, Single and Double Variable Sampling Plans – Chain Sampling Plans – Continuous Sampling Plans: CSP-1, CSP-2 and CSP-3 – Wald-Wolfowitz – Skip-lot Plan. Six Sigma – Implementing Six Sigma – Over View and Implementations – Examples.

Unit – V

Reliability concepts – Components and Systems – Reliability Function – Failure Rate Function – Interrelationship-System. Lifetime Distribution – Exponential, Gamma and Weibull. Bounds on Reliability, Mean Time to Failure, Mean Residual Time – One to one correspondence of these functions – Estimation of Parameters, IFR, DFR Distributions NBUE.

Books for Study and References:

1. Schilling, E.G. (1982): Acceptance Sampling in Quality Control, Marcel Dekker.
2. Montgomary, D.C. (1985): Statistical Quality Control - A Modern Introduction, Sixth Edition, John Wiley.
3. Mittag, H.J. and H. Rinne (1993): Statistical Methods of Quality Assurance, Germany Chapman & Hall, India (UK) – Chapter 3 and 4.
4. Hsyland and Hsyland (2004): System Reliability Theory Models, Statistical Methods, and Applications, Second Edition, Wiley.

Python Programming (20ST08CC) (Credits: 5)

Unit-I

Importing and Exporting Datasets – Sub Setting Dataset – Aggregating Dataset – Stacking and Merging Dataset – For and While loop.

Unit-II

Diagrammatic Representation – Some Basic Distributions (Binomial, Poisson, and Normal) – Measures of Central tendency (Mean, Median and Mode) – Measures of Variability (Range, Variance and Standard Deviation) – Chi-Square Test.

Unit-III

Correlation and Regression – Spearman and Pearson's Correlations, Linear and Multiple Regressions. Experimental Design: One-way ANOVA – Two-way ANOVA – Three-way ANOVA.

Unit-IV

Statistical Quality Control charts – Determination of parameters for constructing basic control charts, such as $\overline{X}$, R, s, p, np, c, u charts.

Unit-V

Decision Tree – Gini Index, CHAID, Classification and Regression Tree Machine Learning – Supervised and Unsupervised Learning.

Books for Study and References:

1. David Amos, Dan Bader, Joanna Jablonski, Fletcher Heisler (2012): Python Basics: A Practical Introduction to Python 3, Real Python.
2. Mark Lutz (2009): Learning Python, Fourth Edition, O'Reilly Media, Inc.
3. Michael Dawson (2010): Python programming for Absolute Beginner, Third Edition, Cengage Learning.
4. Fabio Nelli (2015), Python Data Analytics, Apress.
5. Wes McKinney (2017), Python for Data Analysis Second Edition, O'Reilly.

Statistical Computing Lab - II (20ST09CCL) (Credits: 4)

The Maximum Mark for this Statistical Computing Lab shall be 100 with 25 Marks for Internal Assessment, which comprises Tests and Record Work with manual procedures, and 75 Marks for External Practical Examination. The candidate should attend 3 questions, and each question has 25 marks both the manual and system results. The contents for this Statistical Computing Lab are the problems related to the topics relating to the areas listed below covered in the current semester. The Core Statistical Computing Lab examination is to be conducted at the end of the current Semester. The contents for Statistical Computing Lab shall be restricted to the following topics, which are found in the software **"Python".**

Statistical Inference: Characteristics of a good Estimator: Consistency – Sufficient – Consistency – Unbiasedness – Factorization theorem – Construction of Confidence Intervals for Population Proportion (Small and large Samples) and between two Population Proportions (large Samples) – Confidence Intervals for mean, Variance of a Normal Population – difference between Mean and Ratio of two Normal Populations..

Statistical Quality Control: Parts of Control Charts – Shewhart Control Charts for $\bar{X}$, R, s, p, np, c, u OC and ARL of Control Charts, Control Charts based on C.V. - Economic Designs of Control Charts - Relative Precision - Multivariate Control Charts - Hotelling T^2.

Designs of Experiments: CRD, RBD and LSD - Confounding (Partial and Total) - 2^2, 2^3 and 2^k Factorial Experiments - BIBD - PBIBD - Youden Square Design – Lattice Designs.

Books for Study and References:

1. Radhakrishna Rao. C (2009): Linear Statistical Inference and Its Applications, Wiley.
2. William M. Bolstad (2007): Introduction to Bayesian Statistics, 2nd edition, John Wiley, NY.
3. Mittag, H.J. and H. Rinne (1993): Statistical Methods of Quality Assurance, Germany Chapman & Hall, India (UK) – Chapter 3 and 4.
4. Hsyland and Hsyland (2004): System Reliability Theory Models, Statistical Methods, and Applications, Second Edition, Wiley.
5. Das and Giri (2015): Design and Analysis of Experiments, Second Edition, New Age International Publisher.
6. Cochran, W.G. and Cox, G.M. (1992): Experimental Designs, (2nd Edition) John Wiley.

Statistical Inference-II (20ST10CC)

Unit -I

Testing of Hypotheses: Simple and Composite Hypotheses – Two Types of Errors – Level of Significance – Parametric Test for Population Proportion (Small And Large Samples) and Between Two Population Proportions (Large Samples) – T-Test For Single Mean, Independent Sample Mean, Paired T-test, Significance of Observed Correlation Coefficient and Regression Coefficient – Variance of a Normal Population (Small and Large) – Z-Test – Pearson Correlation – Normality Test.

Unit – II

Non Parametric - U Statistic and Its Property as an Estimator of Its Expected Value – Spearman Correlation – Chi-Square: Association of Attributes, Tests for Goodness of fit, Homogeneity of Variance– Fisher Exact Test – Run Test – Test for Randomness – Median Test – Sign Test – Wilcoxon's Signed Rank Test – Mann-Whitney U Test – Kolmogorov-Smirvov Two Sample Test – Kruskal Wallis – Friedman Test – Mc Nemar's Test.

Unit – III

Most Powerful Test – Neyman-Pearson Lemma-Generalization of Neyman-Pearson Fundamental Lemma– Unbiased Tests – Construction of Uniformly Most Powerful Unbiased Tests for One-Parameter and Multi-Parameter Exponential Family Applications to Standard Statistical Distribution-Similar Regions. Locally Most Powerful (LMP) Test – LMP Unbiased Test.

Unit – IV

Likelihood Ratio (LR) Test – Asymptotic Distribution of LR Test Statistic – Consistency of LR Test – Construction of LR Tests for Standard Statistical Distributions. Monotone Likelihood Ratio Property – Uniformly Most Powerful Tests. Applications to Standard Statistical Distributions.

Unit – V

Introduction to Sequential Procedures – Stopping Times – Wald's Equation. SPRT: Termination Property, Approximation to Stopping Bounds and Applications to Standards Distributions. Wald's Fundamental Identity OC and ASN Functions.

Books for Study:

1. Casella, G. and Berger, R.L. (2002): Statistical Inference (Second Edition). Thompson Learning, New York. (Reprint, 2007).
2. Conover, W.J. (1999): Practical Nonparametric Statistics (Third Edition). John Wiley & Sons, New York. (Reprint, 2007).
3. Radhakrishna Rao, C. (2009): Linear Statistical Inference and its Applications, Wiley; Second edition.
4. Bagdonavicious, Kruopis, Nikulin, M.S. (2011): Non-Parametric Tests for Complete Data, (First Edition), John Wiley and sons, USA.
5. Rajagopalan, M. and Dhanavanthan, P. (2012): Statistical Inference. PHI Learning Pvt. Ltd., New Delhi.

Multivariate Analysis (20ST11CC) (Credits: 5)

Unit – I

Singular and Non-singular Multivariate Normal Distributions and their Properties – Marginal and Conditional Distributions – Characteristic function and Moments – Distribution of Linear Combinations of Multivariate Normal Vector – Determination of Mean and Variance – Covariance Matrix of Multivariate Normal Distribution.

Unit – II

Random Sampling from Multivariate Normal Distribution – Maximum Likelihood Estimators of the Parameters of Multivariate Normal Distribution – Distribution of Sample Mean Vector and Sample Dispersion Mean Vector – Necessary and Sufficient Condition for a Quadratic form to be Distributed as Chi-square – Inference concerning the Sample Mean Vector when Covariance Matrix is known.

Unit – III

Generalized T^2 Statistic and its Distribution – Hotelling's T^2 Statistic and its Distribution - Two sample problems with unequal Covariance Matrices Likelihood ratio Criterion and its Applications – Mahalanobis D^2 Statistic and its Distribution – Applications of Hotelling's T^2 Statistic – Invariance Property of T^2 Statistic – Relationship between T^2 and D^2 Statistics – Behrens – Fisher Problem.

Unit – IV

Wishart distribution – Sampling Distribution of Sample Covariance Matrix – Properties of Wishart Distribution – Wilk's Criterion – Generalized Variance – Sampling Distribution of Simple Sample Correlation Coefficient – Sampling Distribution of Partial and Multiple Correlation Coefficients in null case – Tests Concerning Simple, Partial and Multiple Correlation Coefficients – Discriminant Function – Fisher's Discriminant Function.

Unit – V

Problem of Classification – Two Populations and k Populations – Principal Components and their Determination – Factor Analysis – Estimation of Factor Loadings – Canonical Variables and Canonical Correlations – Derivation of Canonical Correlation Coefficients – Cluster Analysis.

Books for Study:

1. Kotz, S., Balakrishnan, N. and Johnson, N.L. (2000): Continuous Multivariate Distribution Models and Applications (Second Edition). Vol. 1, Wiley-Inter science, New York.
2. Rao, C.R. (2001): Linear Statistical Inference and its Applications (Second Edition). Wiley-Inter Science, New York.
3. Rencher, A.C. (2002): Methods of Multivariate Analysis (Second Edition). Wiley- Interscience, New York.
4. Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis (Third Edition). Wiley–Inter science, New York.
5. Morrison, D.F. (2004): Multivariate Statistical Methods (Fourth Edition). Duxbury Press, New York.
6. Johnson, R.A. and Wichern, D.W. (2013). Applied Multivariate Statistical Analysis (Sixth Edition), Pearson New International Edition.

Statistical Computing Lab - III (20ST12CCP) (Credits: 4)

The Maximum Mark for this Statistical Computing Lab shall be 100 with 25 Marks for Internal Assessment, which comprises Tests and Record Work with manual procedures, and 75 Marks for External Practical Examination. The candidate should attend 3 questions, and each questions have 25 marks both the manual and system results. The contents for this Statistical Computing Lab are the problems related to the topics relating to the areas listed below covered in the current semester. The Core Statistical Computing Lab examination is to be conducted at the end of the current Semester. The contents for Statistical Computing Lab shall be restricted to the following topics, which are found in the software **"R and Python".**

Statistical Inference - II: Parametric Test – t-Test for Single Mean, Independent Sample Mean, Paired t-test, Correlation Coefficient and Regression Coefficient. Non-parametric - Chi-Square test, Run test, Median test, Sign test, Wilcoxon's Signed-Rank test, Mann-Whitney U test, Kolmogorov Smirnov test, Kruskal Wallis test, Friedman Test and Mc Nemar's test. Rank Correlation.

Multivariate Analysis: Multiple Correlation and Partial Correlation - Multiple Regression and Partial Regression – Multiple response frequency – Linear Regression – Hierarchical Multiple Regression – Factor Analysis – Principal Component Analysis – Canonical Correlation – Discriminant functions – Clustering techniques.

Econometrics and Time Series Analysis: Time Series – Trend Analysis – Linear – Parabolic – Exponential – Logistic – Cyclical Variation –Methods – Seasonal Variation – Autocorrelation Functions– Linear Stationary Models – Moving Average, Autoregressive –
ARMA – ARIMA.

Operation Research: Linear Programming Problem – Simplex Method – Dual Simplex Method – Game Theory – LPP and Games – Network Analysis by CPM/PERT – Inventory Theory – Queuing Theory – Simulation.

Books for Study:

1. Box, G.E.P. and Jenkins, G.M. (1976): Time Series Analysis - Forecasting and Control, Holden-Day, San Francisco.
2. Chatfield, C. (2004) The Analysis of Time Series - An Introduction, Sixth edition, Chapman and Hall.
3. Rencher, A.C. (2002): Methods of Multivariate Analysis (Second Edition). Wiley-Interscience, New York.
4. Sharma, J.K. (2010): Operations Research, Theory and Applications, Fourth Edition, McMillan India Ltd.
5. Wooldridge, J. (2012). Introduction Econometrics: A Modern Approach. Cengage Learning.

Statistical Computing Lab - IV (20ST13CCL) (Credits: 4)

The Maximum Mark for this Statistical Computing Lab shall be 100 with 25 Marks for Internal Assessment, which comprises Tests and Record Work with manual procedures, and 75 Marks for External Practical Examination. The candidate should attend 3 questions, and each questions have 25 marks both the manual and system results. The contents for this Statistical Computing Lab are the problems related to the topics relating to the areas listed below covered in the current semester. The Core Statistical Computing Lab examination is to be conducted at the end of the current Semester. The contents for Statistical Computing Lab shall be restricted to the following topics, which are found in the software **"SPSS".**

Survival Analysis: Survival Function of Parametric Models – Exponential, Weibull, Gamma, Geometric Distributions – Non-Parametric – Kaplan-Meier's Method – Cox Proportional Hazard Model – Hazard Ratio. Log Rank Test of Two Groups and Several Groups – Parametric Regression Model – Exponential, Weibull, Cox Proportional Hazard Models – Hazard Function Estimator – Hazard Ratio – Proportional Hazard Model – Exponential, Weibull, Log-Logistic – Counting Process.

Demography and Official Statistics: Crude, Specific, Standardized Death Rates – Life Table – Construction, Use and Interpretation – Force of Mortality – Abridged Life Tables. Fertility – Basic Measurements – Gross and Net Reproduction Rate – Cohort Fertility Analysis – Fertility Models – Components of Population Growth and Change – Models of Population Growth and Their filling to Population Data – Methods of Projection – Logistic Equation – Component Method of Projection – Stable Population Theory.

Books for Study:

1. Cox, D.R. and Oakes, D. (1984) : Analysis of Survival Data, Chapman and Hall, New York.
2. Chow S.C. and Liu J.P. (2004). Design and Analysis of Clinical Trials. 2nd Edn. Marcel Dekkar.
3. Klelin P. John and Moeschberger (2003): Survival Analysis: Techniques for Censored and Truncated Data, 2/e, Springer.
4. Bogue, D.J. (1976): Principles of Demography, John, Wiley, New York.
5. Keyfilz, N. and Caswell, H. (2005) Applied Mathematical Demography, Third edition, Springer.
6. Pollard, A.H., Yusuf, F. and Pollard, G.N. (1990). Demographic Techniques, Pergamon Press, Chapters 1-8, 12.

Project / Dissertation and Viva-Voce (20ST14CCPROJ)

Project / Dissertation shall be carried out under the supervisor of a Faculty member on the recommendation of the Head of the Department. **Three copies** of the Project / Dissertation should be submitted at least two weeks before the last working day of the fourth semester. The Project / Dissertation with components are:

Internal Assessments	**: 25%**
Evaluation of Project / Dissertation by External Examiner and Guide	**: 50%**
Supervisor and External Examiner by Viva-Voce	**: 25%**

The Evaluation of the Project / Dissertation will be based on Project Report and a Viva-Voce Examination to be conducted by the Supervisor and an External Examiner.

DEPARTMENT ELECTIVE COURSES (DEC)

Linear Models and Design of Experiments (20ST01DEC) (Credits: 4)

Unit - I

Linear Models and Linear Model Assumptions on Error Components – Linear Constraints – Orthogonal Contrast – Fixed, Random and Mixed Effects Models with Full Rank and Less Than Full Rank – Gauss-Markov set up and Its Generalization – Linear Estimation – Gauss-Markov Theorem – BLUE – Test for Linear Hypothesis – Review of Basic Designs and Principles of Experimentation CRD – RBD – LSD.

Unit - II

Multiple Comparisons – Multiple Range Tests – Analysis of Covariance – Construction of Orthogonal Latin Square – Concept of Orthogonal Arrays – Analysis of Graeco Latin Squares, Cross Over Designs, Analysis of Non-Orthogonal Two way data – Simple and Balanced.

Unit - III

Construction and Analysis of Factorial Experiments - 2^k, 3^k, S^k – Yates Method – Fractional Factorials – Analysis of Asymmetrical Factorial – Complete and Partial Confounding – 2^k, 3^n – Balanced Confounding in Asymmetrical Factorial Experiments.

Unit - IV

Split Plot Design – Advantages and Disadvantages - Strip Plot Designs – Incomplete Block Designs – Incidence Matrix and Its Properties, Concept of Connectedness and Orthogonality, Balanced Incomplete Block Designs – Construction of BIBD and Analysis – Youden Square Design – Lattice Designs.

Unit – V

Partially Balanced Incomplete Block Design – Construction and Analysis – Resolvable designs – Design for Bioassay – Direct and Indirect – Response Surface Experiments – Characterizing Response Surface – Ridge Systems – First and Second Order Rotatable Designs.

Books for Study and References:

1. Graybill, F.A. (1968): An Introduction to Linear Statistical Models, McGraw Hill.
2. Montgomory, D.C. (1976): Design and Analysis of Experiments, John Wiley and Sons.
3. Nigam, A.K., Puri, P.D. and Gupta, V.K. (1988): Characterizations and Analysis of Block Design, Wiley Eastern.
4. Das and Giri (2015): Design and Analysis of Experiments, Second Edition, New Age International Publisher.
5. Aloke Dey (1986): Theory of Block Designs, Wiley Eastern.
6. Kempthorne, O. (1965): Design and Analysis
7. Cochran, W.G. and Cox, G.M. (1992): Experimental Designs, (2nd Edition) John Wiley.

Stochastic Processes (20ST02DEC) (Credits: 4)

Unit – I

Introduction to Stochastic Processes – Classification of Stochastic Processes, Markov Chain – Markov Chain with Finite and Countable State Space – Markov Process – Transition Probabilities, Transition Probability Matrix – Problems – Chapman-Kolmogorov's Equations, Calculation of n-step Transition Probability and Its Limit – Stationary Distribution.

Unit – II

Classification of States and Chains – Irreducible Chain – Problems – Random Walk and Gambler's Ruin Problem. Markov Process with Discrete State Space – Poisson Processes, Birth and Death Processes, Markov processes with Continuous State Space – Weiner Process, Stationary Processes.

Unit – III

Renewal Processes – Discrete and Continuous Time – Renewal Interval – Renewal Function and Renewal Density – Renewal Equation – Wald's Equation – Renewal Theorems: Elementary Renewal Theorem. Branching Processes

Unit –IV

Galton-Watson Branching Process – Properties of Generating Functions – Ultimate Extinction Probabilities – Distribution of Total Number of Progeny. Strictly Stationary Stochastic Process – Weakly Stationary Stochastic Process – Relationship between Weak and Strict Stationarity – Stochastic Process with Independent Increments.

Unit-V

Stochastic Process with Orthogonal Increments – Poisson Stochastic Process – Gaussian Stochastic Process – Finite-Dimensional Density Function of Gaussian Stochastic Process – Wiener Process (Brownian Motion) – Relationship between Random Walk and Brownian Motion – Filtration Problem.

Books for Study and References:

1. Medhi, J. (1982): Stochastic Process, Fourth edition, New Age International Publisher Pvt Ltd.
2. Karlin, S. and Taylor, H.M. (1975): A First Course in Stochastic Process, Vol.I, Academic Press.
3. Box, G.E.P. and Jenkins, G.M. (1976): Time Series Analysis - Forecasting and Control. Holden-Day, San Francisco.
4. Makridakis, Wheelwright and Hndman (2005): Forecasting – Methods and Applications, Third Edition, Wiley.
5. Granger, C.W.J. and Newbold, (1984) : Forecasting Econometric Time Series, Third Edition, Academic Press.
6. Anderson, T.W. (1971) : The Statistical Analysis of Time Series, Wiley, NY.

ECONOMETRICS (20ST03DEC) (Credits: 4)

Unit – I

Nature and Scope of Econometrics – Illustrative examples of Production and Cost Analysis – Price and Income Elastic Ties of demand – Single Equation – Ordinary Least Square (OLS) Method, Maximum Likelihood Estimate (MLE). General linear model (GLM) and its extensions, Generalized least squares (GLS) Estimation and Prediction, Heteroscedasticity Disturbances, Pure and Mixed Estimation.

Unit – II

Theil BLUS procedure – Estimation and Prediction – Multicollinearity problem – Its Implications and Tools for handling the problem – Ridge Regression. Linear Regression and Stochastic Regression, Instrumental Variable Estimation – Errors in Variables – Autoregressive Linear Regression, Lagged Variables, Distributed Lag Models – Estimation of Lags by OLS Method, Koyck's Geometric Lag Model.

Unit – III

Recursive Systems – 2 SLS Estimators – Limited Information Estimators – K-Class Estimators – 3 SLS Estimator – Full Information Maximum Likelihood Method – Prediction and Simultaneous Confidence Intervals - Simultaneous Linear Equations Model and Its Generalization – Identification Problem, Restrictions on Structural Parameters – Rank and Order Conditions.

Unit – IV

Concepts of Time Series – Applications and Components, Additive and Multiplicative – Diagnostic Checking – Trend Analysis – Linear – Parabolic – Exponential – Logistic – Cyclical, Seasonal and Irregular Variation Discrete Parameter, Auto-Covariance, Autocorrelation and Their Properties. Exploratory Time Series Analysis – Test for Trend and Seasonality – Exponential and Moving Average Smoothing – Holt-Winter Smoothing – Forecasting based on Smoothing. Wold representation of Linear Stationary Processes.

Unit V

Estimation of ARMA Models: Yule-Walker Estimation for AR Processes, Maximum Likelihood and Least Squares Estimation for ARMA Processes, Auto-Covariance and Auto-Correlation Function Under Large Samples Theory – Residual Analysis and Diagnostic Checking. Forecasting using ARIMA Models.

Books for Study:

1. Maddala, G.S. and Kajal Lagari (2009). Introduction to Econometrics. John Wiley & Sons.
2. Madnani, G.M.K. (2008): Introduction to Econometrics: Principles and Applications. Oxford and IBH Publishing.
3. Wooldridge, J. (2012). Introduction Econometrics: A Modern Approach. Cengage Learning.
4. Fuller, W.A. (1978) Introduction to Statistical Time Series, John Wiley.
5. Chatfield, C. (2004) The Analysis of Time Series - An Introduction, Sixth edition, Chapman and Hall.

Survival Analysis and Clinical Trials (20ST04DEC) (Credits: 4)

Unit – I

Introduction to Survival Analysis – Definitions and Properties – Concepts of Time, Order and Random Censoring, Likelihood in These Cases – Life Distributions – Exponential, Gamma, Weibull, Lognormal, Pareto, Linear Failure Rate. Parametric Inference – Longitudinal Studies – Censoring Mechanisms – Type I, Type II and Left Right and Interval Censoring – Likelihood Functions under Censoring and Estimation– Tests based on LR, MLE.

Unit – II

Life Tables – Failure Rate – Mean Residual Life and Their Elementary Properties – Concept of Ageing – Types of Ageing Classes and Their Properties – Estimation of Survival Function – Actuarial Estimator, Kaplan-Meier Estimator, Estimation under Assumption of IFR / DFR. Tests of Exponentiality Against Non-Parametric Classes Total Time on Test – Two Sample Problem – Gehan Test – Log Rank Test.

Unit – III

Introduction To Semi-Parametric Regression for Failure Rate – Cox's Proportional Hazards (PH) Model With One and Several Covariates – Estimation Problems in Cox's PH Model – Rank Test for Regression Coefficients. Introduction to Competing Risks Analysis and Estimation Problems in Competing Risk Model for Parametric and Non-Parametric, Semi-Parametric Models.

Unit – IV

Introduction to Clinical Trials: The Need and Ethics of Clinical Trials – Bias and Random Error in Clinical Studies – Conduct of Clinical Trials – Overview of Phase I - IV Trials – Multicenter Trials. Data Management: Data Definitions – Case Report Forms – Database Design – Data Collection Systems for Good Clinical Practice.

Unit – V

Design of Clinical Trials: Parallel Vs. Cross-Over Designs – Cross-Sectional Vs. Longitudinal Designs – Review of Factorial Designs – Objectives and Endpoints of Clinical Trials – Design of Phase I Trials – Design of Single-Stage and Multi-Stage Phase II Trials – Design and Monitoring of Phase III Trials with Sequential Stopping. Reporting and Analysis: Analysis of Categorical Outcomes From Phase I-III Trials– Analysis of Survival Data from Clinical Trials.

Books for Study and Reference:

1. Cox, D.R. and Oakes, D. (1984) : Analysis of Survival Data, Chapman and Hall, NewYork.
2. Chow S.C. and Liu J.P.(2009). Design and Analysis of Bioavailability and bioequivalence. 3rd Edn. CRC Press.
3. Chow S.C. and Liu J.P. (2004). Design and Analysis of Clinical Trials. 2nd Edn. Marcel Dekkar
4. Deshpande, J.V. and Purohit S.G. (2005). Life Time Data: Statistical Models and Methods, Word Scientific.
5. Hosmer D.W., Lemeshow S. and May S. (2008): Applied Survival Analysis: Regression Modeling of Time-to-Event Data (2nd Edition), John Wiley& Sons, Inc.
6. Klelin P. John and Moeschberger (2003): Survival Analysis: Techniques for Censored and Truncated Data, 2/e, Springer.

Demography and Official Statistics (20ST05DEC) (Credits: 4)

Unit – I

Development and Scope of Demography – Demographic Data: Sources and Current Status – Chandrashekar-Deming Index – Adjustment of Age Data – Use of Whipple – Myer and UN Indices – Population Size and Growth in India - Trends and Differentials in World Population – Health Surveys and Use of Hospital Statistics – Population Transition Theory.

Unit – II

Mortality – Basic Measurements – Crude, Specific, Standardized Death Rates – Life Table – Construction, Use and Interpretation – Force of Mortality – Abridged Life Tables. Fertility – Basic Measurements – Gross and Net Reproduction Rate – Cohort Fertility Analysis – Fertility Models – Population Regulation Programs in India – Demographic Transition Theory.

Unit – III

Special Distribution of Population – Basic Concepts – Measurements and Models of Migration – Concept of International Migration – Urban Development Components of Urban and Metropolitan Growth – Urbanization in Developed and Developing Countries – Stable and Quasi Populations – Intrinsic Growth Rate.

Unit – IV

Components of Population Growth and Change – Models of Population Growth and Their Filling to Population Data – Methods of Projection – Logistic Equation – Component Method of Projection – Stable Population Theory – Decennial Population Census in India – Nuptiality and Its Measurements.

Unit – V

Official Statistics – Present Official Statistical System in India – Relating to Population, Agriculture, Industrial Production, Trade and Prices – Methods of Collection of Official Statistics – Their Reliability and Limitations – Principal Publications Containing such Statistics – Various Official Agencies Responsible for Data Collection and Their Main Functions – Ministry of Statistics and Programme Implementation (MoSPI), Social Statistics Division (SSD), Economic Statistics Division (ESD), Price Statistics Division (PSD) and NSSTA Training Division.

Books for Study and References:

1. Bogue D.J. (1976): Principles of Demography, John, Wiley, New York.
2. Gibbs, J.P. (2012). Urban Research Methods. Literary Licensing, LLC.
3. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. II, 9th Edn., World Press.
4. Keyfitz, N (1977): Applied Mathematical Demography- Springer Verlag.
5. Keyfilz, N. and Caswell, H. (2005) Applied Mathematical Demography, Third edition, Springer.
6. Mukhopadhyay P. (1999): Applied Statistics, Books and Allied (P) Ltd.
7. Peter R. Cox (2008): Demography (5th Edition), Cambridge University Press, New York.
8. Statistical System in India (CSO) 1995.
9. Guide to Official Statistics (CSO) 1999.

Statistical Genetics (20ST06DEC) (Credits: 4)

Unit - I

Physical Basis of Inheritance – Analysis of Segregation, Detection and Estimation of Linkage for Qualitative Characters – Amount of Information about Linkage – Combined Estimation – Disturbed Segregation.

Unit - II

Gene and Genotypic Frequencies – Random Mating and Hardy-Weinberg Law – Application and Extension of Equilibrium Law – Fisher's Fundamental Theorem of Natural Selection – Disequilibrium due to Linkage for Two Pairs of Genes – Sex-Linked Genes – Theory of Path Coefficients.

Unit - III

Concepts of Inbreeding – Regular System of Inbreeding – Forces Affecting Gene Frequency – Selection, Mutation and Migration – Equilibrium between Forces in Large Populations – Random Genetic Drift – Effect of Finite Population Size.

Unit - IV

Polygenic System for Quantitative Characters – Concepts of Breeding Value and Dominance Deviation – Genetic Variance and Its Partitioning – Effect of Inbreeding on Quantitative Characters – Multiple Allelism in Continuous Variation – Sex-Linked Genes – Maternal Effects – Estimation of Their Contribution – Correlations between Relatives, Heritability, Repeatability and Genetic Correlation.

Unit - V

Response due to Selection: Selection Index and Its Applications in Plants and Animals Improvement Programmes – Correlated Response To Selection.

Restricted Selection Index: Variance Component and Linear Regression Approach for Analysis of Genetic Engineering Interactions – Measurement of Stability and Adaptability for Genotypes – Concepts of General and Specific Combining Ability – Diallel and Partial Diallel Crosses – Construction and Analysis.

Books for Study and References:

1. Balding, DJ, Bishop, M and Cannings, C. (2001). Hand Book of Statistical Genetics. John Wiley.
2. Crow, JF and Kimura, M. (1970). An Introduction of Population Genetics Theory. Harper &Row.
3. Dahlberg, G. (1948). Mathematical Methods for Population Genetics. Inter Science Publ.
4. Ewens, WJ. (1979). Mathematics of Population Genetics. Springer.
5. Falconer, DS. (1985). Introduction to Quantitative Genetics. ELBL.
6. Lerner, IM. (1954). Genetic Homeostasis. Oliver & Boyd.
7. Lerner, IM. (1958). The Genetic Theory of Selection. John Wiley.
8. Li, CC. (1982). Population Genetics. The University of Chicago Press.
9. Mather, K and Jinks, JL. (1977). Introduction to Biometrical Genetics. Chapman & Hall.
10. Mather, K and Jinks, JL. (1982). Biometrical Genetics. Chapman & Hall.
11. Narain, P. (1990). Statistical Genetics. Wiley Eastern.

Applied Regression Analysis (20ST07DEC) (Credits: 4)

Unit – I

Simple Linear Regression Models – Least Square Estimation of Parameters – Properties of Least Square Estimator – Estimation by Maximum Likelihood Method – Multiple Linear Regression Model – Estimation of Parameters – Hypothesis Testing in Multiple Linear Regression – Confidence Intervals, Prediction of New Observations – Gauss-Markov Models – Best Linear Unbiased Estimators – Test For Linear Hypothesis.

Unit – II

PRESS Statistic – Outliers Lack of Fit – Transformations – Variance Stabilizing – Linearzing Model – Box-Cox Method – Transformation and Regressor Variables – Diagnostics for Leverage and Influence – Measure of Influence – Cook's D-Model Performance – Detection and Treating Influential Observations – Elementary Regression Diagnostics.

Unit – III

Polynomial Regression Models – Piecewise Polynomial Fitting (Splines) – Nonparametric – Kernel – Loess – Orthogonal Polynomials – Indicator Variables – Basic Concepts – Sources – Multicollinearity Diagnostics – Methods for Dealing With Multicollinearity – Model Respecification – Ridge Regression.

Unit – IV

Robust Regression – Methods of Robust Estimation – Least Absolute Deviations – M Estimators – Properties of Robust Estimators – High Break Down Point Estimators – Bound Influence Estimator – Nonlinear Regression Models – Non-Linear Least Squares – Transformation to A Linear Model – Parameter Estimation – Linearization.

Unit-V

Generalized Linear Models – Logistic Regression Models – Estimation, Interpretation of Parameters – Multinomial – Ordinal – Poisson Regression – Link Functions and Linear Predictors – Prediction and Estimation – Bootstrapping and Re-Sampling in Regression Models.

Books for Study and References:

1. Chatterjee, S, Ali S. Hadi and Price, B. (1999): Regression Analysis by Example, 3rd edition, John Wiley.
2. Douglas C. Montgomery and Elizabeth A. Peck, (2013): Introduction to linear Regression Analysis, John Wiley & Sons, New York.
3. Draper, N.R. and Smith, H. (1998): Applied Regression Analysis, 3rd Edn., John Wiley.
4. Gunst, R.F. and Mason, R.L. (1980): Regression Analysis and Applications – A Data Oriented Approach, Marcel Dekker.

Statistical Methods for Bioinformatics (20ST08DEC) (Credits: 4)

Unit - I

Introduction to Bioinformatics: Definition and History of Bioinformatics – Internet and Bioinformatics – Introduction to Data Mining – Applications of Data Mining to Bioinformatics Problems and Applications of Bioinformatics.

Unit - II

Bio-computing: Introduction to String Matching Algorithms – Database Search Techniques – Sequence Comparison and Alignment Techniques – Use of Biochemical Scoring Matrices – Introduction to Graph Matching Algorithms – Automated Genome Comparison and its Implication – Automated Gene Prediction – Automated Identification of Bacterial and Pathways – Introduction to Signalling Pathways and Pathway Regulation – Gene Arrays – Analysis of Gene Arrays.

Unit - III

Statistical Testing and Significance for Large Biological Data Analysis – Statistical Testing – Parametric and Non-parametric Tests – Resampling Tests – hoc Tests – Error Controlling – Multiple Testing Problems and Procedures – Applications.

Unit - IV

Overview of Bioinformatics – Human Genome Project – Goals of Human Genome Project – Bioinformatics and Internet – Useful Bioinformatics Sites on World Wide Web – Basic Principles of Computing in Bioinformatics: Running Computer Software – Computer Operating System – Software Downloading and Installation.

Unit - V

Databases: Data Life Cycle Acquisition – Modification – Uses – Archiving – Repurposing – Disposal – Database Technology Architecture and Management System – Interfaces, Software and Programming Languages – Examples of Bioinformatics Database – Use of Databases: Structure Databases – Visualization of Structural Data – Pattern Matching – Molecular Modelling – Mapping Databases – Genomic Mapping – Types of Maps – Overview on Phylogenetic Analysis – Collaboration.

Books for Study and References:

1. Bailey, N.T.J. (1995): Statistical Methods in Biology, Third Edition, Cambridge law.
2. Baldi, P. and Brunak, S. (1998): Bioinformatics, The MIT Press.
3. Baldi, P. and Brunak, S. Bioinformatics: The Machine Learning Approach.
4. Bergeron, B. (2003): Bioinformatics Computing, Prentice Hall Inc. Eastern Economy Edn.
5. Jae K. Lee, (2010): Statistical Bioinformatics. Wiley-Blackwell, New Jersey.
6. Lesk, A.M. (2002): Introduction to Bioinformatics. Oxford University Press.

Financial Statistics (20ST09DEC) (Credits: 4)

UNIT I

Introduction – Probability and Its Distributions – Sampling Distributions: T, F, Chi-Square Distributions – Skewness and Kurtosis – Law of Large Numbers and Central Limit Theorem – Multivariate Normal Distributions: Correlation and Covariance – Independence and Covariance – Linear Functions of Random Variables.

UNIT II

Net Returns – Gross Returns – Log Returns – Adjustment for Dividends – Behavior of Returns – Random Walk Models – Origins of Random Walk Hypothesis – Efficient Markets Hypothesis – Discrete and Continuous Compounding.

UNIT III

Time Series Data – Stationary Processes: Weak White Noise – Predicting White Noise – Estimating The Parameters of Stationary Process – Moving Average (MA) Processes – ARIMA Processes – AIC and SBC - GE Daily Returns: AR Order - Three-Month Treasury Bill Rates – Forecasting GE Daily Log Returns and Log Prices.

UNIT IV

Portfolio Theory: Trading Off Expected Return and Risk – One Risky Asset and One-Risk Free Asset – Two Risky Assets – Combining Two Risky Assets with Risk Free Asset – Quadratic Programming – Utility Theory.

UNIT V

Regime Switching Models: Bull and Bear Markets – Regression on Bull3 – Other Models for Bull/Bear – Bull and Bear Portfolios – Copulae and Value at Risk.

Books for Study and References:

1. Borowiak, D.S. and Shapiro, A.F. (2013). Financial and Actuarial Statistics: An Introduction (Second Edition). CRC press.
2. Carmona, R. (2012). Statistical Analysis of Financial Data in S-Plus. Springer.
3. Rachev, S.T., Hoechstoetter, M., Fabozzi, F.J. and S.M. Focardi, (2010). Probability and Statistics for Finance. John Wiley & Sons.
4. Ruppert, D. (2004). Statistics and Finance: An Introduction. Springer Texts in Statistics
5. Sclove, S.L. (2012). A Course on Statistics for Finance. CRC press.

Time Series Analysis (20ST10DEC) (Credits: 4)

UNIT I

Models of Time Series – Additive And Multiplicative Models – Analysis and Forecasting – Elimination of Trend – Growth Curve – Modified Experimental Curve (Method of Three Selected Points Only) - Gompertz Curve- Logistic Curve with Examples.

UNIT II

Stationary Processes – Auto-Covariance and Autocorrelation Functions and Their Properties – Partial Auto-Correlation Function - Estimation of Autocorrelation and Its Standard Error – Unit Root Test.

UNIT III

Linear Stationary Models - Stationary and Invertability – Autoregressive and Moving Average Processes and Their Autocorrelation Functions- Autoregressive Moving Average Processes – Linear Non-Stationary Models – Autoregressive Integrated Moving Average Processes – Seasonal Autoregressive Integrated Moving Average Processes.

UNIT IV

Box-Jenkins Models – Identification Techniques – Initial Estimates for Different Processes – AR, MA, ARMA – Stationary and Non-Stationary Models – Model Diagnostic – Model Multiplicity – Study of Residuals and Diagnostic Checking – Use of Computer Packages for the above Techniques.

UNIT V

Spectral Analysis of Weakly Stationary Processes – Periodogram and Correlogram Analysis including Computations Based on Fourier Transform – Use of Spectral Representation to show the Existence of Autoregressive Processes and Their Representation – One-Sided Moving Average Processes.

Books for Study and References:

1. Anderson, T. W. (2011): The Statistical Analysis of Time Series, John Wiley & Sons.
2. Bloomfield, P. (2004): Fourier analysis of Time Series - An introduction (Second Edition), John Wiley & Sons.
3. Box, G.E.P. and Jenkins, G.M. and Reinsel, G.C. (2013): Time Series Analysis - Forecasting and Control (Fourth Edition), Holden- Day, San Francisco.
4. Brockwell, P.J. and Davis, R.A. (2002): Introduction to Time Series and Forecasting, Taylor & Francis.
5. Chatfield, C. (1978): The Analysis of Time Series - Theory and Practice (Third Edition), Chapman and Hall, London.
6. Gupta, S.C. and Kapoor, V.K. (2007): Fundamentals of Applied Statistics (Fourth Edition), Sultan Chand & Sons Company, New Delhi.
7. Hannan, E.J. (1960): Time Series Analysis, Methuen, London.
8. Kendall, M.G. and Stuart, A. (1976): The advanced theory of Statistics, Vol.3, Charles Griffin, London.
9. Montgomery, D.C. and Johnson, L.A. (1977): Forecasting and Time Series analysis, McGraw.

UNIVERSITY ELECTIVE COURSES (UEC)

Operations Research (20ST01UEC) (Credits: 3)

Unit – I

Linear Programming Problem – Statement Basic Theorems and Properties – Simplex Method – Two Phase Method – Principle of Duality – Dual Simplex Method – Transportation Problem – Assignment Problems – Sequencing and Scheduling Problem – Processing n jobs through 2, K Machines.

Unit – II

Game Theory – Zero–Sum Games by Dominance Principle, Graphical Solutions of 2x2, 2xn and mx2 Games – Minimax and Maximin Principle and Saddle Point Theorems – Mixed Strategies – Saddle Points – Dynamic Programming – LPP and Games.

Unit – III

Network Analysis by CPM/PERT – Basic Concept – Constraints in Network – Construction of the Network – Time Calculations – Concept of Slack and Float in Network Analysis – Network Crashing – Finding Optimum Project Duration and Minimum Project Cost.

Unit – IV

Inventory Theory – Costs involved in Inventory Problems – EOQ – Deterministic Model – Economic Lot Size Models without Shortages and with Shortages having Production Rate Infinite and Finite – Sensitivity Analysis – Inventory with Uncertain Demand – Systems of Inventory Control – Fixed Order Quantity System (Q-system) – Periodic Review System (P-system).

Unit- V

Queuing Theory – Characteristics of Queuing Systems – Steady State M/M/1, M/M/1 with Limited Waiting Space – M/M/C – M/M/C with Limited Waiting Space – Non-Poisson Queuing Models – $M/E_k/1$, M/G/1 Problems.

Replacement Theory – Replacement of Items – Group Replacement.

Simulation: Scope – Role and Generation of Random Number – Generation of Random Numbers by Multiplicative – Congruential Method – Monte-Carlo Simulation.

Books for Study and References:

1. Taha, H.A. (1982): Operations Research, Third Edition, Collier-MacMillan.
2. Paneerselvam. R, (2006): Operations Research, Third Edition, Prentice Hall of India.
3. J.K. Sharma, (2010): Operations Research, Theory and Applications, Fourth Edition, McMillan India Ltd.
4. Philips. D.T., Ravindran, A. and Solberg, J.J. (1991): Operations Research Principles and Practice.

Bio-Statistics (20ST02UEC) (Credits: 3)

Unit - I

Nature and Scope of Biological and Clinical Experiments and Data – Classification of Data – Need and Nature of Tabulation – Charts and Diagrams for Data – Bar Diagrams, Pie Diagrams, Pictograms, Histograms – Frequency Curves and Their Use.

Unit - II

Measures of Central Tendency – Mean, Median, Mode, Geometric Mean, Use of These Averages in Biological Studies – Measures of Deviation and Standard Deviation – Co-Efficient of Variation – Measure of Skewness and Kurtosis.

Unit - III

Correlation and Regression Theory – Correlation Coefficient – Rank Correlation – Regression Equations (Only Problems) – Multiple and Partial Correlation and Regression. Basic Concepts of Sampling – Simple Random Sample – Stratified Sample – Systematic Samples.

Unit - IV

Test of Significance Based on Large Sample Test : For Mean – Variance and Proportions – Test for Means, Variance and Attributes Using T, F and Chi-Square Distribution. Test for Correlation Regression Coefficients – Chi-Square Test for Goodness of Fit.

Unit - V

Analysis of Variance: One Way and Two Way Classifications – Completely Randomized Blocks – Randomized Block Design and Latin Square Design (Simple Problems Based on Biological and Biochemical Data).

Books for Study and References:

1. Campbell, R.C. (1989): Statistics for Biologists. Cambridge University Press, London.
2. Daniel, W.W. (2008): Bio-Statistics: A Foundation for Analysis in the Health Science. John Wiley & Sons, Incorporated.
3. Glantz, S.A. (2012): Primer of Bio-Statistics (Seventh Edition). McGraw-Hill Professional Publishing, USA.
4. Sokal, R.R. and Rohlf, F.J. (1969). Biometry: The Principles and Practice of Statistics in Biological Research (Third Edition). San Francisco, California, Freeman and Company.

Industrial Statistics (20ST03UEC) (Credits: 3)

Unit – I

Historical development of Statistical Quality Control – Meaning of Quality improvement – Quality cost – Total Quality Management – Causes of Variations – Control Charts for $\bar{X}$, R, s, p, np, c, u, etc.

Unit – II

Acceptance Sampling Plans by Attributes – Single Sampling Plan – Double Sampling Plan – OC curves – AOQ, ATI curves, Dodge Roaming AOQL and LTPD Plans, MIL – STD 105D Plans.

Unit – III

Variable Sampling Plan – One sided and Two Sided Specifications – Taguchi Philosophy and Contributions to Quality Improvement (Basic concepts only).

Unit – IV

Test of Significance and Design of Experiments: Tests based on t, F and Chi-square Distributions – Analysis of Variance – One Way and Two Way Classification of Complete Randomized Design, Randomized Block Design, Latin Square Design.

Unit – V

Basic of Reliability Theory – Life Time Distribution – Hazard Rate – Survival Function – MTTF – MRL, Computations of Exponential, Weibull, Gamma and Life Time Distributions.

Books for Study and References:

1. Montgomery, D.C. (1991): Introduction of Statistical Quality Control, John Wiley and Sons.
2. Marvin Rausand, (2004): System Reliability theory- Models, methods and Applications, John Wiley and Sons.
3. Hsyland and Hsyland, (2004): System Reliability Theory Models, Statistical Methods, and Applications Second Edition, Wiley
4. Mittag, H.J. and Rinne, H. (1993): Statistical Methods of Quality Assurance, Germany Chapman & Hall India (UK) – Chapter 3 and 4.
5. Das and Giri, (2015): Design and Analysis of Experiments, 2nd edition, New Age International Publisher.

VALUE ADDED COURSE (VAC)

Induction to Machine Learning (20ST01VAC) (Credits: 2)

Unit – I

Machine learning – Genetic algorithm – Support Vector Machines – Applications – Cluster Analysis – Methods of Similarity – Methods of Distance Measurement – Similarity Co-efficient – Similarity Matrix – Types of Clustering Techniques – Neural Network.

Unit – II

Model Estimation – Resampling Methods – Cross-Validation – Leave-One Out-Rotation – Bootstrap – Algorithms for Classification and Regression – Naïve Bayes – Problem of Zero Frequency – Missing Values and Numeric Attributes – Multiple Regression – Logistic Regression – K-Nearest Neighbour Classification and Prediction.

Unit – III

Decision Tree – Concepts – Construction of Rules – Basic Concepts – Constructing of Classification Trees – Inductive Decision Tree – Version3 for Nominal Attributes – Information Entropy – Building Tree – Gain-High Branching Attributes – Top-Down ID – C4.5.

Unit – IV

Chi-Square Automatic Interaction Detection – Algorithm and Description – Applications – Classification and Regression Trees – Impurity Measure – Ginni Index – Applications – Towing Index – Ordered Index.

Unit – V

Regression Trees – Concepts – Tree Based Regression – Least Square Regression Trees – Greedy Criterion – Resubstitution – Over Fitting Pruning – Types – Subtree Replacement and Raising – Pruning Algorithms – Cost Complexity – Minimum Error – Pessimistic – Critical Value.

Books for Study and References:

1. Alex Smola and Vishwanathan, SVN (2008): Introduction to Machine Learning, Cambridge University.
2. Judith Hurwitz and Daniel Kirsch (2018): Machine Learning for Dummies, IBM Limited Edition, John Wiley & Sons, Inc.
3. Marc Peter Deisenroth, Aldo Faisal, A. and Cheng Soon Ong, (2020): Mathematics for Machine Learning, Cambridge University.
4. Nils J. Nilsson, (2005): Introduction to Machine Learning, Stanford University.

Introduction to Big Data Analytics (20ST02VAC) (Credits: 2)

Unit - I

Introduction – Big Data – Definition – Classification of Digital Data – Structured and Unstructured Data – Characteristics – Evolution – Challenges with Big Data – Other Characteristics of Data – Terminologies used in Big Data Environments – Basically Available Soft State Eventual Consistency.

Unit - II

Big Data Tools – Hadoop, Spark, Impala, etc. – Data ETL process – Identify Gaps in Data – Follow-up for Decision Making – Provide Data/information in Standard Formats. Knowledge Management – Standardized Reporting and Compliances – Decision Models.

Unit - III

Data Analytics – Nature of Data – Relational Databases to Big Data – Key-value Store – Simplest Class of Analytics – Data Sources to Suffice Business Requirement – Descriptive Statistics for all Variables – Observer the Data Ranges – Outlier Detection and Elimination.

Unit - IV

Data Visualization – Prepare the data for Visualization – Use tools – Tableau, QlickView and 03, Draw insights out of Visualization Tool – Product Implementation.

Unit - V

Cloud Computing – Overview – Origin – Cloud Components – Essential Characteristics – On-demand Self-service – Broad Network Access – Location Independent Resource Pooling – Rapid Elasticity – Measured Service – Comparing Cloud Providers with Traditional IT Service Providers – Roots of Cloud Computing.

Books for Study and Reference:

1. Chuck Lam (2010): Hadoop In Action, Dreamtech Publications.
2. Cloud Computing (2008): Web-Based Applications That Change the Way You Work and Collaborate Online, Michael Miller.
3. Dirk Deroos, Paul C.Zikopoulos, Roman B.Melnky, Bruce Brown, Rafael Coss (2014): Hadoop For Dummies, Wiley Publications.
4. Judith Huruwitz, Alan Nugent, Fern Halper, Marcia Kaufman (2013): Big data for dummies, John Wiley & Sons, Inc.
5. Paul Zikopoulos (2012): Understanding Big Data Analytics for Enterprise Class Hadoop and Streaming Data, McGraw Hill.
6. Robert D.Schneider (2012): Hadoop for Dummies, John Wiley & Sons, Inc.
7. Seema Acharya, Subhashini Chellappan, (2015): Big Data and Analytics First Edition, Wiley Publications.
8. Tom White(2015): Hadoop The Definitive Guide, O'Reilly Publications, Fourth Edition.

Advanced Excel and Data Analysis (20ST03VAC) (Credit: 2)

The Maximum Mark for this paper shall be 100 with 25 Marks for Internal Assessment, which comprises Tests, and 75 Marks for External Examination. The candidate should attend 3 questions 25 Mark each with internal choice. The contents for this paper are the problems related to the papers covered in all the semesters. The topics relating to the areas listed below covered under Semester I . The Core Statistical Software Practical examination is to be conducted at the end of the I Semester. The contents for Statistical Software Practical shall be restricted to the following topics, which are found in the software "**Excel"**

Unit-I

Excel Introduction – Mathematical Functions – Text Functions – Upper, Lower, Proper, Left, Concatenate and Substitute- Date and Time Functions- Advanced Paste Special Techniques – Charts and Slicers – Various Charts using Slicers – Sorting and Filtering.

Unit-II

What is Analysis – Goal Seek-Scenario Analysis – Data Tables (PMT functions) – Solver Tool – Logical Functions – If functions, Fix Errors, Nested If, Complex If, AND/OR Functions – Lookup Functions – Vlookup / Hlookup – Index and Match – Nested Vlookup – Reverse Lookup using Choose Function.

Unit-III

Pivot Tables – Creating Simple Pivot Tables – Basic and Advanced Value Field Setting – Classic Pivot Table – Grouping Based on Number and Dates – Excel Dashboard – Planning a Dashboard – Adding Tables and Charts and Dynamic Contents.

Unit-IV

Introduction To VBA Macro – Variables in VBA – Non Declared Variables – Using Constant Variables – INPUTBOX Functions – Various Button Groups in VBA – If And Select Statements – Looping In VBA – Main Functions in VBA.

Unit- V

Data Analysis VBA – Descriptive Statistics, Z Test, T-Test, F-Test – One Way ANOVA – Regression.

Books for Study and References:

1. Advanced excel-www.tutorialpoint.com
2. Excel Advanced 2007-http://www.mousetraining.co.uk
3. Excel VBA Advanced- Microsoft Application Series

Advanced Data Analysis using SPSS (20ST04VAC) (credit-2)

The Maximum Mark for this paper shall be 100 with 25 Marks for Internal Assessment, which comprises Tests and Record work, and 75 Marks for External Examination. The candidate should attend 3 questions 25 Marks each with internal choice. The contents for this paper are the problems related to the papers covered in all the semesters. Problem relating to the areas listed below covered under Semester I to II. The Core Statistical Software Practical examination is to be conducted at the end of the II Semester. The contents for Statistical Software Practical shall be restricted to the following topics, which are found in the software "**SPSS".**

1. Correlation & Regression – Partial and Multiple Correlations, Linear and Multiple Regression.
2. Curve Fitting, Time Series and Forecasting Models.
3. Inferential Statistics for Single through Multiple Samples (Chi square, t and f test).
4. Non-parametric Tests – Run Test, Sign Test, Median Test, Mann-Whitney U Test, Kruskal Walli's test, Fried Man Test.
5. Experimental Design: One Way ANOVA – Two Way ANOVA – Factorial Designs – Multiple Comparison Tests – Multivariate ANOVA – ANCOVA.
6. Multivariate : Principal Component Analysis – Factor Analysis.
7. Statistical Quality Control Charts – Determination of Parameters for Constructing Basic Control Charts – $\bar{X}$, R, S, p, np, c, u Charts.
8. Cluster Analysis – Discriminant Analysis – Classification and Decision Trees – Artificial Neural Network.

Books for Study and References:

1. Andy Field, (2011): Discovering Statistics Using SPSS 3rd edition, Sage Publications Ltd.
2. George and Mallery (2011): SPSS for Windows Step by Step, 10th edition, Pearson Education in South Asia.